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U.S. Army MP 2-75
Coast Eng.
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MP 2-75
(AD-A009-500)

Guidelines for Monitoring Shore Protection Structures in the Great Lakes

MISCELLANEOUS PAPER 2-75
FEBRUARY 1975



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U.S. ARMY, CORPS OF ENGINEERS
COASTAL ENGINEERING
RESEARCH CENTER

Kingman Building
Fort Belvoir Va. 22060

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PREFACE

This report is published to assist in the collection of reliable, quantitative data on the behavior of shore erosion control structures in the Great Lakes. Although these guidelines are oriented for use in the Great Lakes, many features are applicable to any coastal zone. The work in preparing these guidelines was carried out under the coastal construction research program of the U.S. Army Coastal Engineering Research Center (CERC).

This report was prepared by the staff of the Engineering Development Division of CERC. Special acknowledgment is expressed to Messrs. Dennis W. Berg and Adrian J. Combe III for their technical contributions to these guidelines. The guidelines were reviewed in the early stage of preparation by the U.S. Army Engineer Division, North Central, Corps of Engineers; comments and suggestions from the Division Engineer, North Central, were incorporated into the final report.

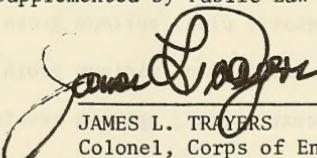
The Coastal Engineering Research Center and its predecessor, the Beach Erosion Board, have published numerous technical papers concerning coastal engineering and the oceanographic forces which affect the coast. Information and copies of these publications may be obtained from:

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Comments on this publication are invited.

Approved for publication in accordance with Public Law 166, 79th Congress, approved 31 July 1945, as supplemented by Public Law 172, 88th Congress, approved 7 November 1963.



JAMES L. TRAVERS
Colonel, Corps of Engineers
Commander and Director

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GUIDELINES FOR MONITORING SHORE PROTECTION STRUCTURES IN THE GREAT LAKES

I. INTRODUCTION

In recent years increased rates of shore erosion in the Great Lakes have resulted from unusually high water levels, although erosion may continue at any level of the lakes (Berg, 1965). Erosion is especially critical where the shore is characterized by narrow beaches backed by bluffs or high dunes. Landslides often result on this type of shore when high waves, caused by storms over the lake, attack the base of bluffs or dunes. The landslide material that falls onto the beach or into the water is then attacked by the waves; since most of this material is generally fine it is moved offshore and alongshore, out of the area. An irretrievable loss of consolidated land results and potential loss of buildings and associated development is threatened.

If the loss of land is too costly or the shoreline is retreating too fast, it may be necessary to install some type of shore protection structure to prevent complete loss of upland development. The Coastal Engineering Research Center (CERC) has published a comprehensive manual concerned with designing coastal structures for shore stabilization or navigation improvement (U.S. Army, Corps of Engineers, Coastal Engineering Research Center, 1973).

Alternative shore protection methods for a given problem are presented along with construction guidelines in a *Help Yourself* brochure recently published by the U.S. Army Engineer Division, North Central¹.

Since the extent of damage caused by waves is difficult to predict, it is advisable to monitor the behavior of the lakeshore after construction of a protective structure. In this way the effectiveness of the shore protection can be determined. To ensure best results from a monitoring program, the method used to determine erosion rates and performance of the protective structure must be systematic. These guidelines provide methods for determining changes in location of the shore and bluff, and for analyzing the effectiveness of various types of structures which may be installed. The guidelines are intended for use by city, county, and State agencies in setting up and managing data collection on the behavior of shore erosion control structures. A glossary of terms is included in Appendix A.

II. METHODS FOR RECORDING SHORELINE CHANGES

An optimum program for recording shoreline changes is to survey profiles near property lines and at the center of the property using standard surveying techniques (Allen, 1931; Ruby, Lommel, and Todd, 1950;

¹This brochure may be obtained free of charge by writing to: Department of the Army, North Central Division, Corps of Engineers, 536 S. Clark Street, Chicago, Illinois 60605.

Breed, Hosmer, and Bone, 1958) three times each year on a regular schedule in addition to surveys after major storms (Fig. 1). Historical profile data, if available for the region being monitored, may exhibit some depth below which no significant changes in bathymetry occur; profiles should then be surveyed to this depth. If historical data are not available, profiles should extend to the -12-foot contour. Past experience in the Great Lakes suggests that only minor changes in bathymetry occur lakeward of this contour.

Elevations or depth measurements should be referenced to the International Great Lakes Datum (IGLD). Table 1 gives IGLD elevations of low water datum (LWD) for each of the Great Lakes, including maximum and minimum stage of record.

A minimum program for recording shoreline changes is to measure the distance from a building to the water's edge and the length of the property lines in early spring, mid-summer, and late fall (Fig. 2). These lengths should be measured in a horizontal plane and extend out to the shoreline or to a convenient wading depth. The location of the top of a bluff or dune should be noted in all cases (Fig. 3).

An optimum surveillance program could be downgraded to a minimum program after 2 years if analysis of the survey data indicates that extensive survey coverage is not warranted. Programs can be developed on an individual basis anywhere between the minimum and the optimum, e.g., the program could be weekly surveys using the Jacob's Staff Method (Emery, 1961; and Urban and Galvin, 1969) or thrice-yearly surveys using standard survey methods (Allen, 1931; Ruby, Lommel, and Todd, 1950; and Breed, Hosmer, and Bone, 1958). Typical survey schemes for minimum and optimum survey programs for three structure types are shown in Figures 4 through 9.

III. MONITORING SHORE PROTECTION STRUCTURES

A program to monitor shore protection structures should continue for at least 3 years, providing the structure does not fail in the meantime. If one of the purposes of the program is to determine the economic or effective life of the structure, it generally will be necessary to continue the monitoring longer than 3 years. A surveillance program should, as a minimum, cover three cycles of the normal expected storm segments of the year. For the Great Lakes this would include three periods of late fall or early spring. In some cases longer periods of monitoring will be required to ensure adequate measurements covering periods of exposure to changing conditions.

The following items of data collection should be included in the surveillance program of the constructed works:

a. Condition Surveys. Hydrographic and topographic surveys, including dimensions and elevations of the shore protection structure referenced to survey monuments, should be made immediately before and

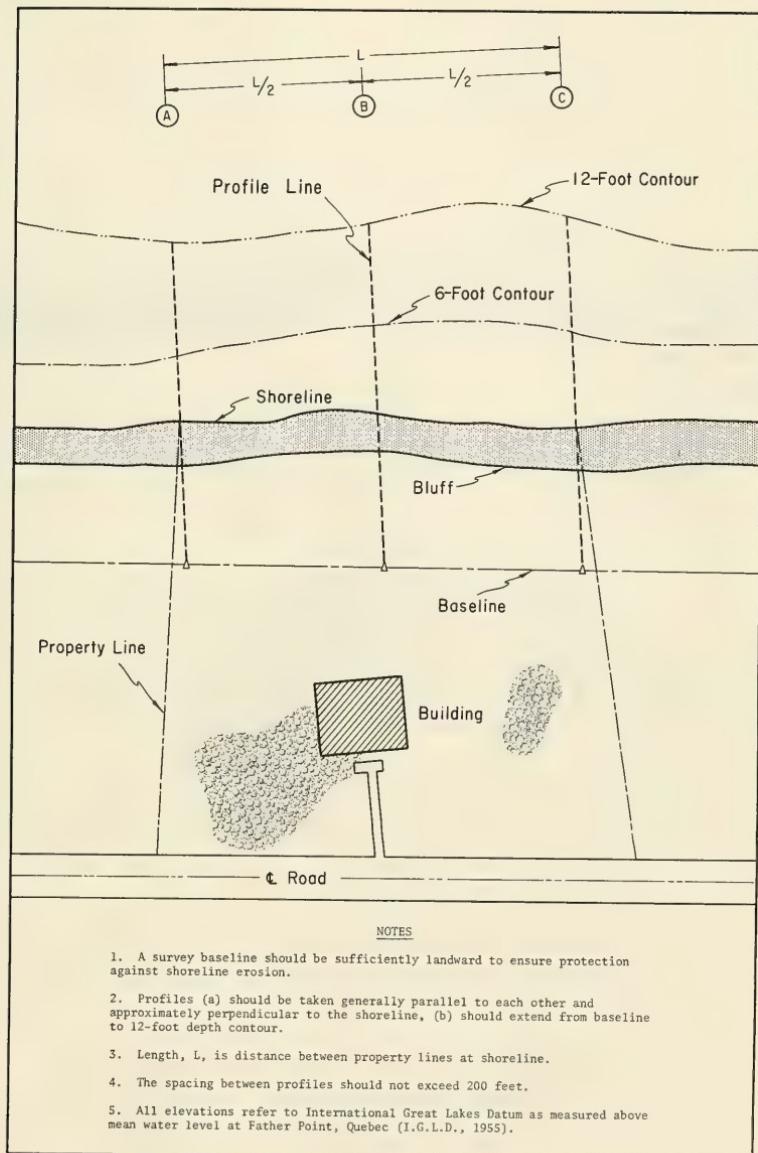


Figure 1. Schematic plan; optimum shoreline surveillance program.

Table 1. Monthly average lake levels¹

Levels	Lake Superior	Lake Michigan-Huron	Lake St. Clair	Lake Erie	Lake Ontario
Maximum Stage ²	602.3	582.0	576.2	573.5	248.0
Lake Datum ²	600.0	576.8	571.7	568.6	242.8
Minimum Stage ²	598.3	575.4	569.9	567.5	241.4

1. Recorded lake levels for the preceding 18 months and probable levels for a 6-month period can be obtained from:

Monthly Bulletin of Lake Levels
 Lake Survey Center, NOAA
 U.S. Department of Commerce
 630 Federal Building and U.S. Courthouse
 Detroit, Michigan 48226

2. International Great Lakes Datum (1955). Elevations are in feet above mean water level in Gulf of St. Lawrence at Father Point, Quebec, Canada.

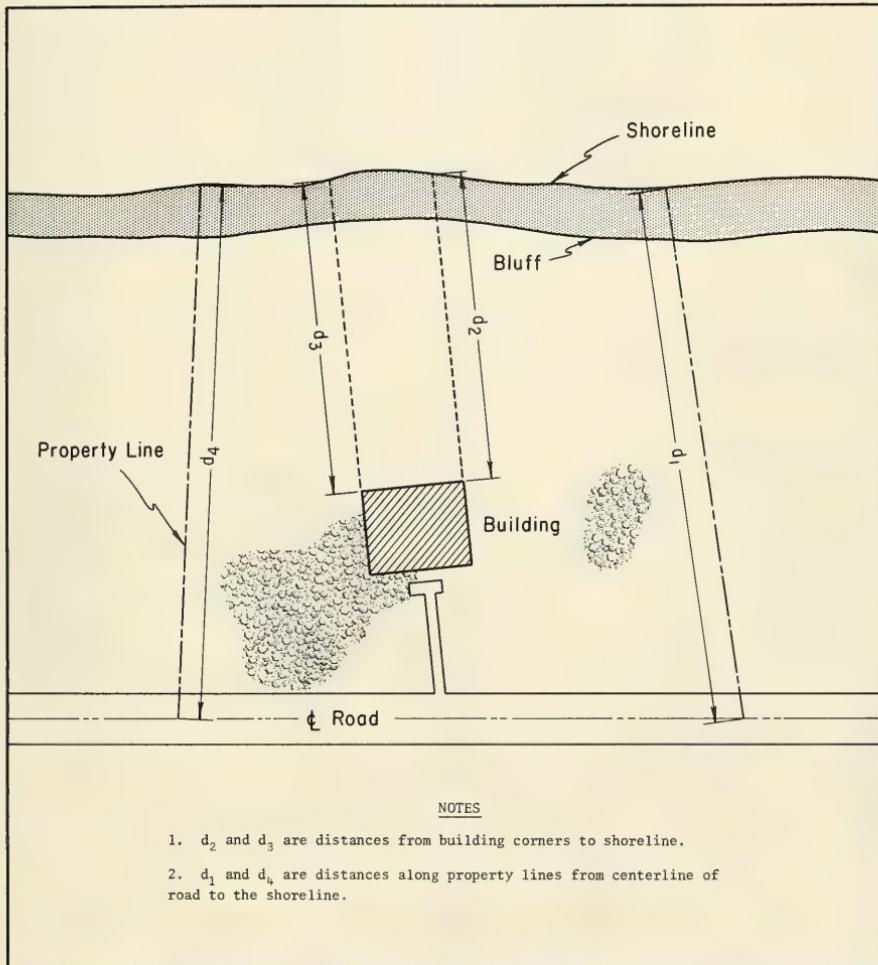


Figure 2. Schematic plan; minimum shoreline surveillance program.

NOTES

1. Distance measurements must be horizontal level lines.
2. If profiles are taken instead of distance measurements, obtain elevations at changes in grade or every 20 feet.
3. If ground has low relief, use judgment in spacing out profile points.
4. All elevations refer to International Great Lakes Datum as measured above mean water level at Father Point, Quebec (I.G.L.D., 1955).

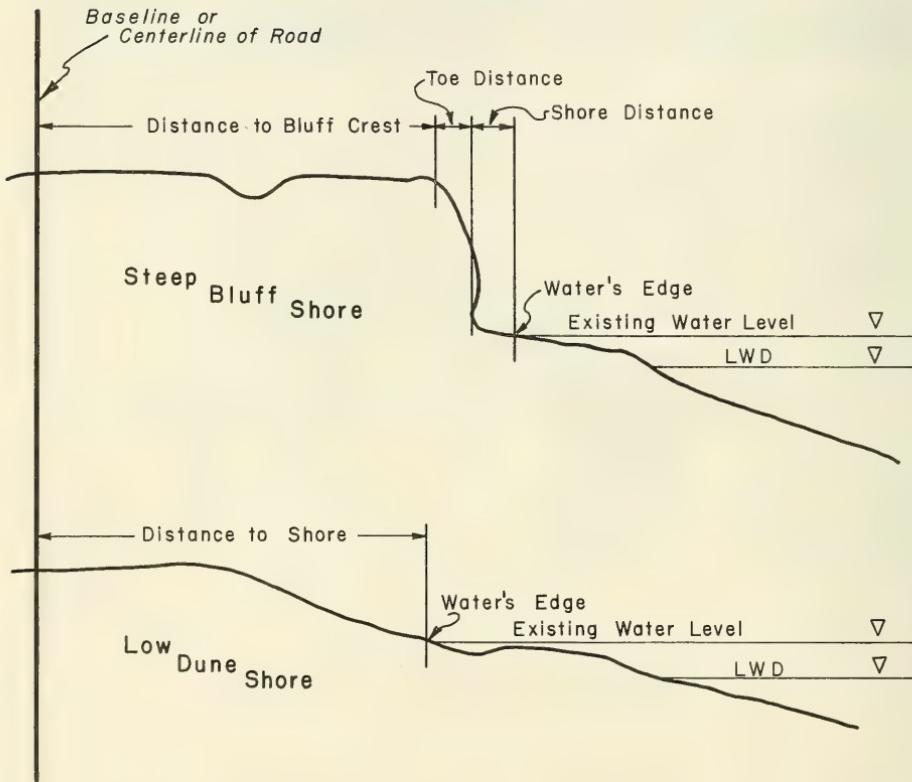


Figure 3. Typical distance measurements.

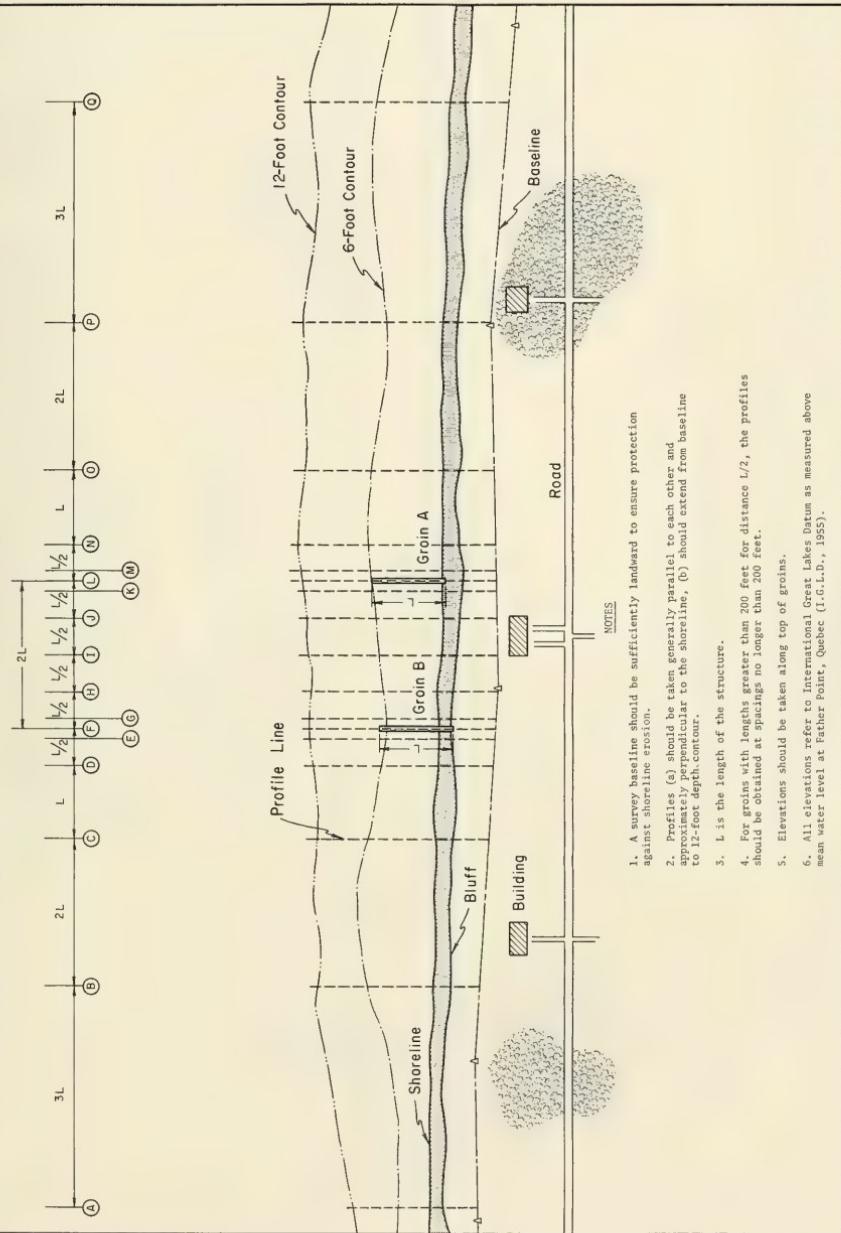
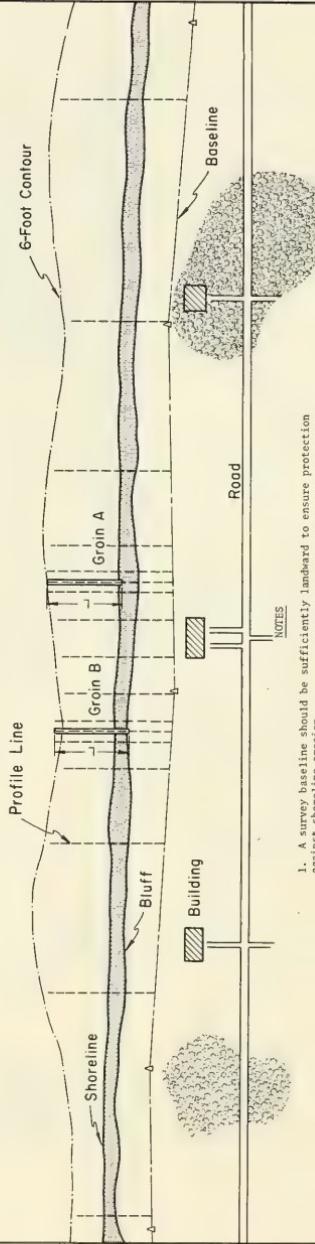
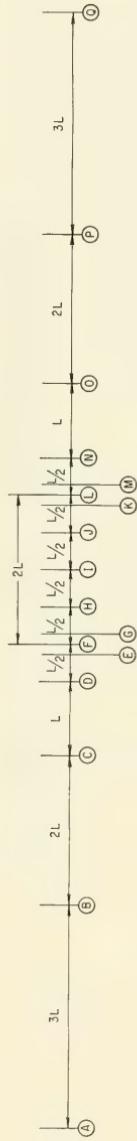


Figure 4. Schematic plan; optimum groin surveillance program.



NOTES

1. A survey baseline should be sufficiently landward to ensure protection against shoreline erosion.
2. Profiles (a) should be taken generally parallel to each other and approximately perpendicular to the shoreline, (b) should extend from baseline to 5-foot depth contour.
3. L is the length of the structure.
4. For groins with lengths greater than 200 feet for distance $L/2$, the profiles should be obtained at spacings no longer than 200 feet.
5. Elevations should be taken along top of groins.
6. All elevations refer to International Great Lakes Datum as measured above mean water level at Father Point, Quebec (I.G.L.D., 1955).

Figure 5. Schematic plan; minimum groin surveillance program.

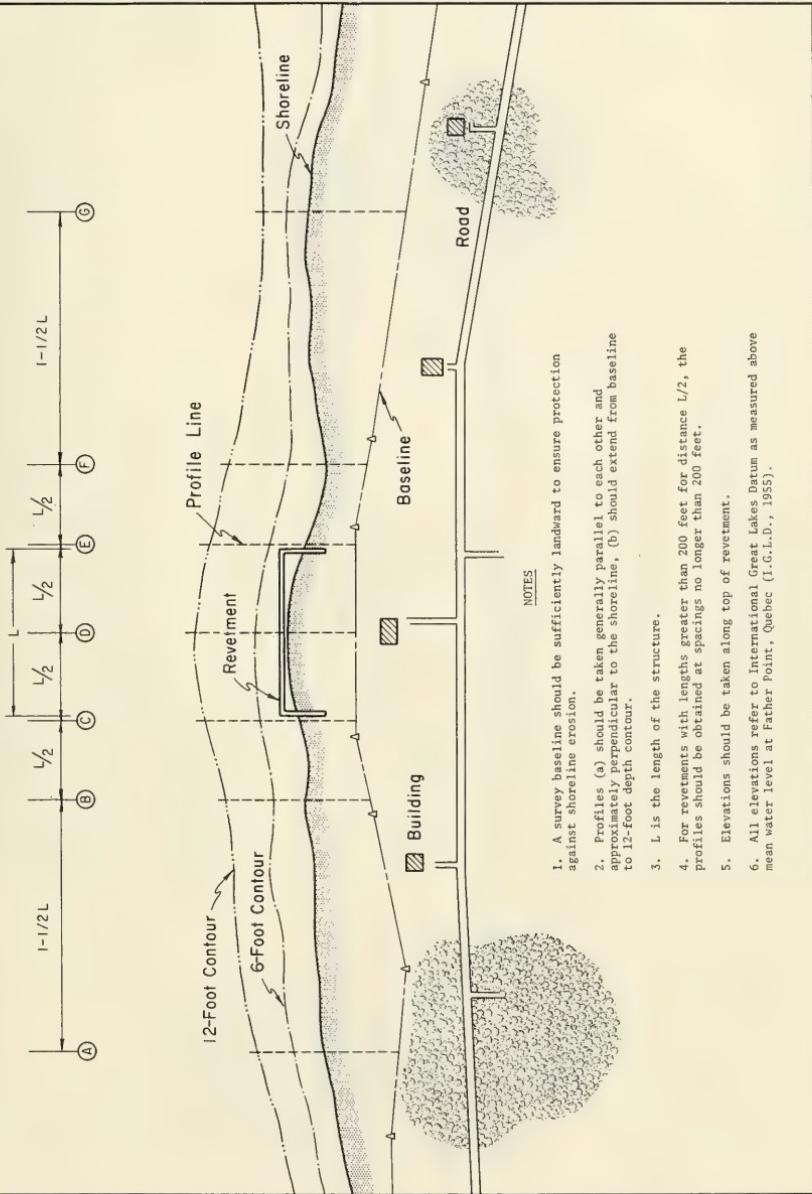


Figure 6. Schematic plan; optimum revetment surveillance program.

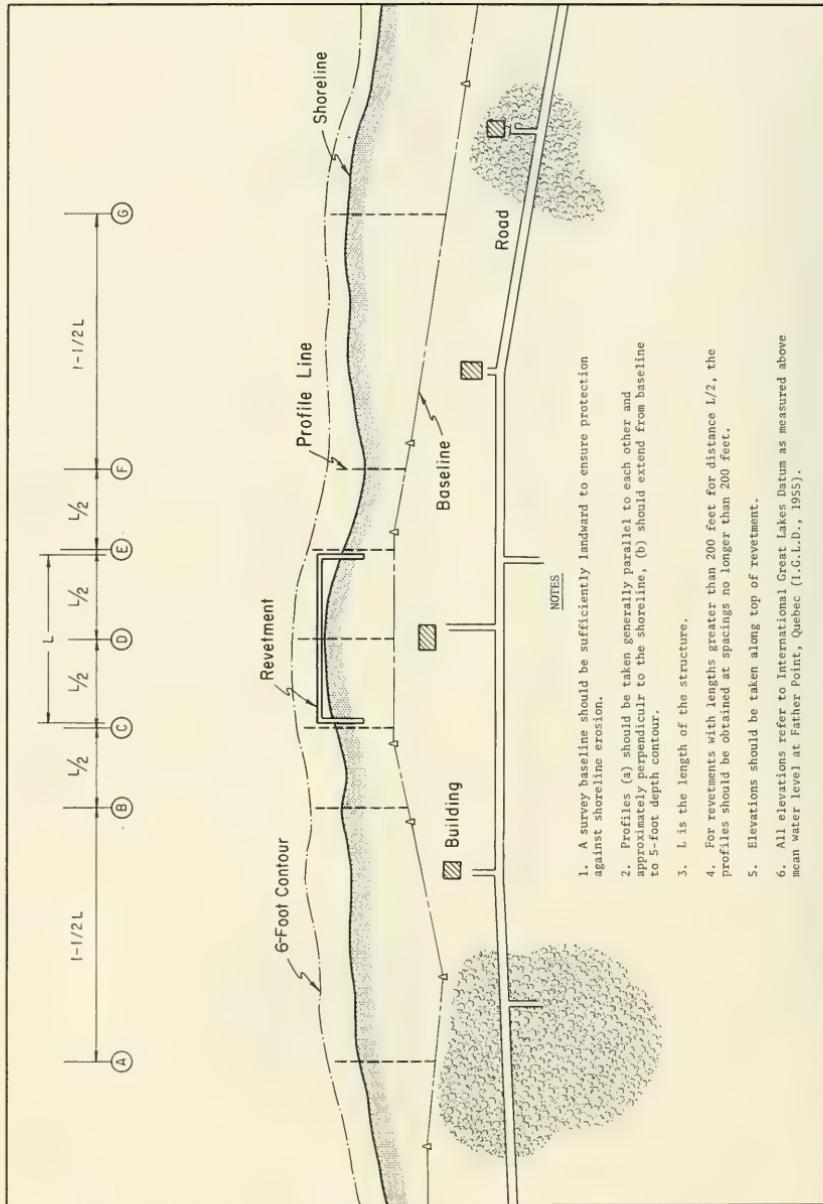
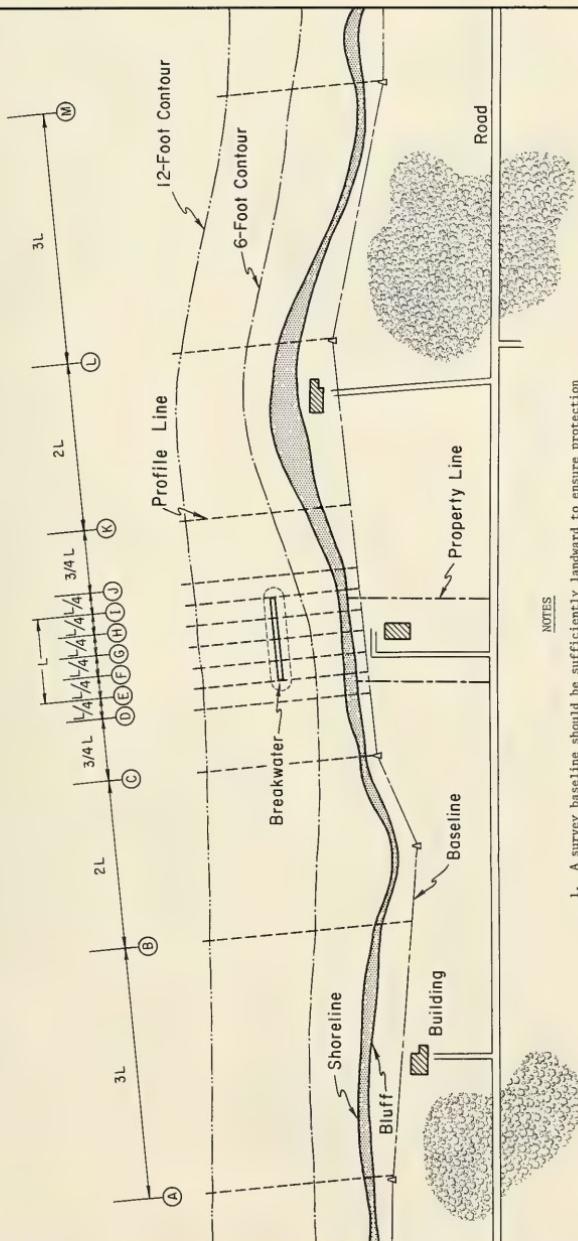


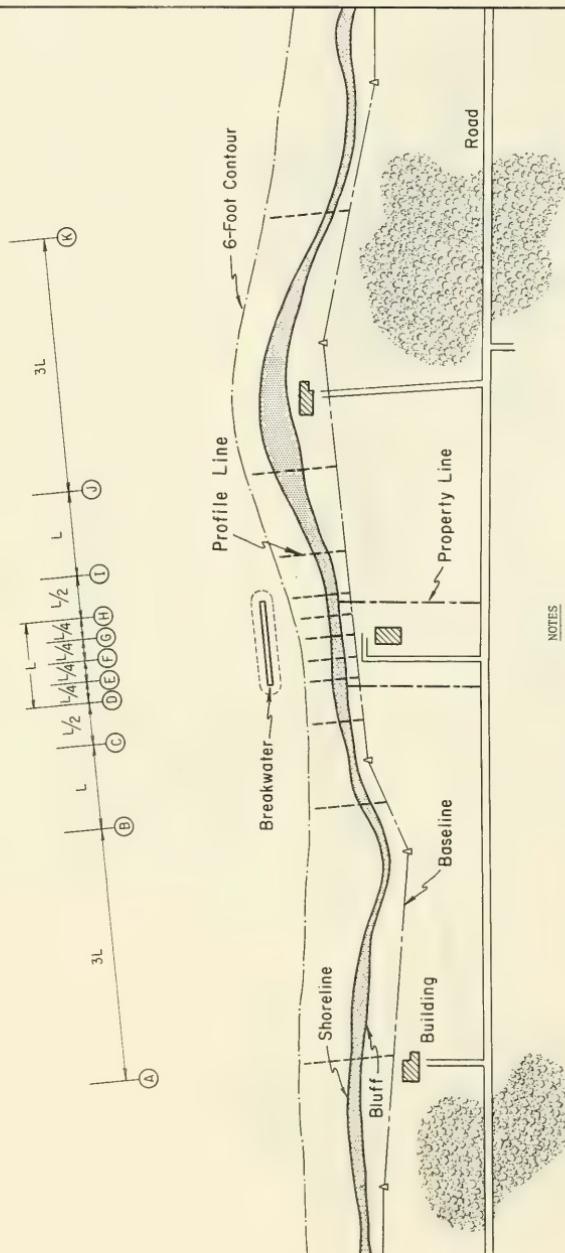
Figure 7. Schematic plan; minimum revetment surveillance program.



NOTES

1. A survey baseline should be sufficiently landward to ensure protection against shoreline erosion.
2. Profiles (a) should be taken generally parallel to each other and approximately perpendicular to the shoreline, (b) should extend from baseline to 12-foot depth contour.
3. L is the length of the structure.
4. For breakwaters with lengths greater than 200 feet for distance $L/4$, the profiles should be obtained at spacing no longer than 200 feet.
5. All elevations refer to International Great Lakes Datum as measured above mean water level at Father Point, Quebec (I.G.L.D., 1955).

Figure 8. Schematic plan; optimum breakwater surveillance program.



NOTES

1. A survey baseline should be sufficiently landward to ensure protection against shoreline erosion.
2. Profiles (a) should be taken generally parallel to each other and approximately perpendicular to the shoreline, (b) should extend from baseline to 5-foot depth contour.
3. L is length of structure.
4. For breakwaters with lengths greater than 200 feet for distance $L/4$, the profiles should be obtained at spacings no longer than 200 feet.
5. All elevations refer to International Great Lakes Datum as measured above mean water level at Father Point, Quebec (I.G.L.D., 1955).

Figure 9. Schematic plan; minimum breakwater surveillance program.

after construction. The optimum survey frequency is three repeat surveys per year (early spring, mid-summer, and late fall) using standard surveying techniques. The minimum desirable survey frequency is two repeat surveys, in early spring and late fall.

b. Supplemental Data. In monitoring the behavior of shore protection structures, the following supplemental data should be obtained:

(1) Photography. Photograph the installation from two or more permanent locations immediately after construction. Repeat the photographs with each condition survey.

(2) Plans and Specifications. Obtain all available documents.

(3) Materials. List types, quantities, and costs of structural materials.

(4) Labor. List type, quantities, and costs for labor.

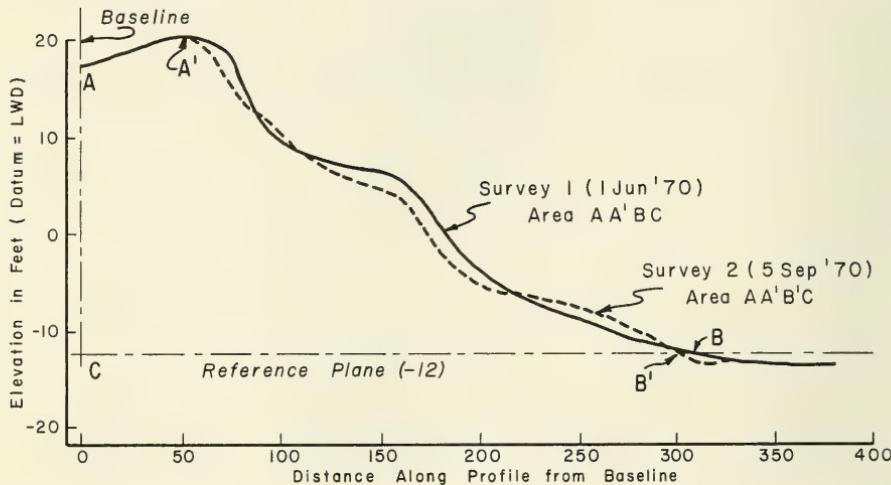
(5) Maintenance. Record the frequency, time, materials and cost, and labor and costs required to effect repairs.

(6) Ownership. Provide as much information as practicable about ownership and responsibility for the structure. Sample forms for obtaining and recording this supplemental data are given in Appendix B.

c. Wave and Currents. The availability of statistical wave and current data (Berg, 1969; Szuwalski, 1970; and Bruno and Hiipaka, 1973) should be investigated with the local U.S. Army Engineer Districts (Fig. 10). Short-term water level rises associated with local storm winds can affect the structure function and life. These vary from locality to locality. Information on specific occurrences affecting the monitored-structure should be obtained from the appropriate U.S. Army Engineer Districts (Fig. 10) or the Lake Survey Center, National Oceanic and Atmospheric Administration (NOAA) (Table 1). It should be emphasized that an accurate record must be kept of dates of surveys, photographs and other items relating to the surveillance program.

In addition to surveillance of the functional behavior of a shore protection structure, observation of the structural behavior of the installation is also important. Shore protection structures require varying degrees of maintenance depending upon structure type and degree of exposure to wave action. Information on maintaining protective structures is given in Table 2. The surveillance program should include provisions for special inspections of the structure after storms in addition to regular or periodic inspections.

If failure of the structure occurs, all possible data should be obtained on the type and time of failure, and the wave and water level conditions to which it was subjected at the time of failure.



$$\text{Unit Volume for Survey 1} = V_u = \frac{L_u A}{27} = \frac{(1\text{ ft.})(5265\text{ ft.}^2)}{27\text{ ft.}^3/\text{yd.}} = 195 \text{ Cu. Yd.}$$

$$\text{Unit Volume for Survey 2} = V_u = \frac{L_u A}{27} = \frac{(1\text{ ft.})(4955\text{ ft.}^2)}{27\text{ ft.}^3/\text{yd.}} = 184 \text{ Cu. Yd.}$$

$$\text{Change in Unit Volume} = \Delta V_u = 184 - 195 = -11 \text{ Cu. Yd.}$$

$$\text{Annual Rate} = \frac{\Delta V_u (365)}{(t_2 - t_1)} = \frac{(184\text{ yd}^3 - 195\text{ yd}^3)(365\text{ days})}{(5\text{ Sep '70} - 1\text{ Jun '70})(96\text{ days})} = -42 \text{ Cu. Yd.}$$

Figure 10. Example of profiles and volumetric change computation.

Table 2. Maintenance requirements for shore protection structure

Type of Structure	Signs of Failure	Causes of Failure	Maintenance or Repair Procedure
Stone revetment or broken concrete revetment.	Excessive settlement, increased voids and loss of filter material, erosion behind or at end of structure.	Scour at toe, flanking undersized stone or inadequate height, improper placement.	Place additional rock at toe; restore to original elevation section and thickness; reduce excessive void ratio; backfill behind structure; extensive upgrading in size of material may be required.
Gabion revetment; stone-filled wire mattress.	Broken wire, excessive movement, erosion behind or at ends of structure.	Scour at toe, flanking excessive strain caused by displacement, rusting, and inadequate height.	Replace all broken wires and reinforce at points of severe strain with No. 9 wire ties.
Sacked concrete, slope paving, gobi block paving.	Any movement, cracks in surface, undercut end sections, erosion at toe or behind structure.	Subsidence undermining, flanking, sliding and hydrostatic pressure, inadequate height.	Restore structure to original section after each storm; backfill behind structure.
Crib or fence revetment. Large concrete-filled bags. Small sandbags.	Rocking, broken wires or members, excessive displacement, erosion behind structure.	Rusting, rotting, theft of materials, vandalism, subsidence, flanking, sliding, and inadequate height.	Reestablish support by backfilling, construction or underpinning, and foundation protection. Reopen weep holes; fill cracks with a suitable sealing material.
Groins, steel, concrete, timber.	Loss of fill material, erosion behind the groin, and tipping.	Flanking, scouring at end of structure, inadequate penetration. Lack of littoral drift.	Replace broken and weakened wires or mesh as necessary. Replace missing parts, add additional cables. These structures are relatively low cost and may require replacement after major storms.
Seawalls, steel, concrete, timber.	Lakeward movement, erosion behind at the toe or at the end of structure.	Loss of foundation support, inadequate penetration, scour at toe, flanking, inadequate height.	Fill groins with beach material; provide riprap toe protection at end of groin. Place additional rock at mid point to stabilize structure; add bulkhead at landward end to prevent flanking.
Offshore breakwaters, perched beach, or jetties.	Excessive movement of structure, settling displacement, or rock-facing material.	Foundation failure, undersize stone, inadequate section.	Reestablish support by underpinning, tie backs, systems of anchor piling, walers and tie rods. Place rock or rockfilled mattress at toe of structure to prevent scour. Backfill where necessary.
			Restore structure to original section. Extensive upgrading in size of material may be required.

IV. COMPUTATION OF SHORELINE CHANGES

Shoreline changes are generally expressed as feet of horizontal movement, or volumetric change per foot of beach per year. The rate of horizontal advance or retreat is the algebraic of distances measured along the same line perpendicular to the shore between successive surveys converted to an annual basis. Volumetric accretion and erosion rates are usually computed using the average end-area method (Allen, 1931; Ruby, Lommel, and Todd, 1950; and Breed, Hosmer, and Bone, 1958) as given by the formula:

$$V = \frac{L}{27} \frac{(A_1 + A_2)}{2}$$

where the volume is in cubic yards and the length, L, is the distance in feet between the two profiles, and A_1 and A_2 are the areas at each profile between the surveyed surface and an arbitrary datum elevation. The volume at the later survey date is subtracted from the volume at the earlier survey date so that a positive result indicates accretion and a negative result indicates erosion. The result is then divided by the distance, L, and converted to an annual basis in cubic yards per foot of beach per year.

Assuming that the distance between adjacent profiles is about the same, and that the locations of the profiles are representative of the section of beach being studied, the volumetric computation can be simplified by modifying the average end-area formula. This is accomplished by replacing the distance between profiles with a unit length, L_u (e.g., 1 foot). The result is that at each profile, a volume is computed using the formula:

$$V_u = \frac{L_u}{27} X A$$

where V_u is the unit volume in cubic yards per foot of beach at the profile location; L_u is the unit length (e.g., 1 foot); A is the area between the surveyed ground line and a reference plane, usually the deepest depth of survey (at least -12 feet) in the Great Lakes; and the factor 27 converts from cubic feet to cubic yards. These unit volumes at each profile from one survey can be compared with unit volumes from other surveys at the same profile and reduced to annual volumetric accretion rates at the profile. After tabulating these values for the beach being studied, the means (averages) are easily calculated. An example of this computation is given in Figure 10.

V. DATA ANALYSIS

After a system of monitoring programs has been established in an area, the city, county, or State beach erosion district should begin to collate the data collected on the behavior of shore protection structures. Initially, data should be collated from 10 shoreline types

which may occur in the area (Table 3). Then, this division should be further subdivided into the five primary structural groups: *groins, seawalls and bulkheads, offshore breakwaters, revetments, and miscellaneous types*. For each subcategory, the shoreline change rate, volumetric accretion rate, and supplemental data should be compiled. The final output from this data compilation should result in guidelines for shore property owners on what methods result in the greatest benefits per dollar invested. If a substantial number of structures of one type are studied, that subdivision could be further subdivided into concrete, steel, timber, and rubble-mound types.

Table 3. Categories of upland shore types

Code	Type
A	Artificial fill area
HBE	High bluff erodible, 30 feet or higher
HBN	High bluff nonerodible, 30 feet or higher
LBE	Low bluff erodible, less than 30 feet high
LBN	Low bluff nonerodible, less than 30 feet high
HD	High sand dune, 30 feet or higher
LD	Low sand dune, less than 30 feet high
PE	Erodible low plain
PN	Nonerodible low plain
W	Wetlands

VI. CONCLUDING REMARKS

The primary reasons for monitoring shore protection structures are to determine if structural maintenance is required and at what cost, and to evaluate whether the installation is effective in combating erosion. A program to maintain structural integrity must continue throughout the life of the structure. These guidelines contain minimum and optimum programs for evaluating the effectiveness of shore protection structures. The concept that a small amount of data is better than none is not always valid, because the small amount of data may indicate performance for a year that is completely different from the long-range, average annual performance. Unless sufficient systematically collected data are gathered for a number of structures, it will be difficult if not impossible to evaluate the relative effectiveness or economy of different structures.

Assistance in establishing a monitoring program can be obtained from a U.S. Army Engineer Division or District office, Division and District boundaries, and offices for the Great Lakes, with addresses and phone numbers are shown in Figure 11.

**U.S. ARMY CORPS OF ENGINEERS
DIVISION AND DISTRICT
BOUNDARIES
(NORTH CENTRAL)**

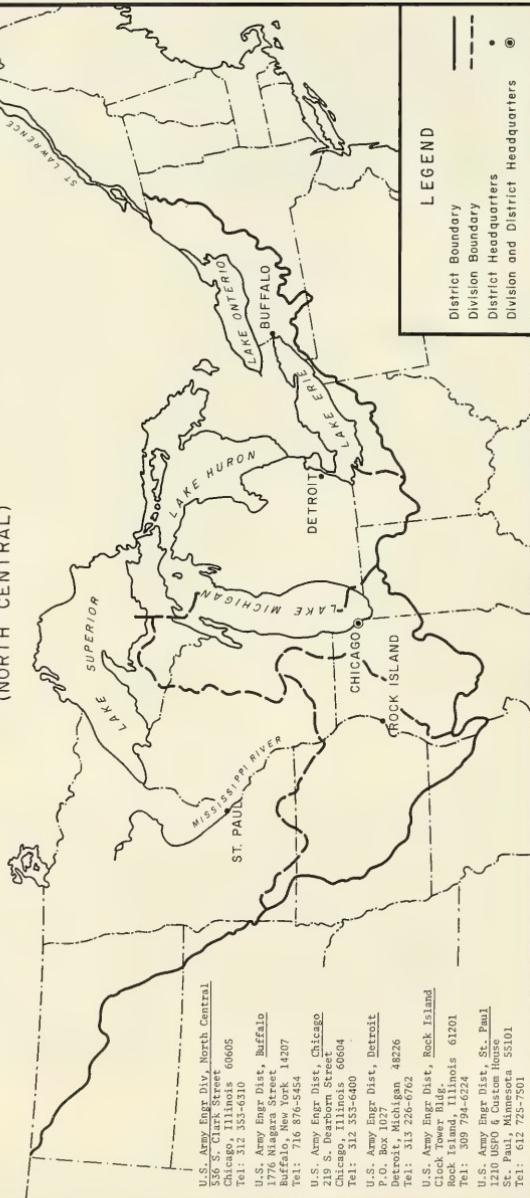


Figure 1. U.S. Army Engineer Division and District boundaries and offices for the Great Lakes (North Central).

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APPENDIX A

GLOSSARY OF SELECTED COASTAL ENGINEERING TERMS¹

ACCRETION - May be either Natural or ARTIFICIAL. Natural accretion is the buildup of land solely by the action of the forces of nature, on a BEACH by deposition of waterborne or airborne material. Artificial accretion is a similar buildup of land by reason of an act of man, such as the accretion formed by a groin, breakwater, or beach fill deposited by mechanical means.

ALONGSHORE - Parallel to and near the shoreline; same as LONGSHORE.

ARTIFICIAL NOURISHMENT - The process of replenishing a beach with material (usually sand) obtained from another location.

BACKSHORE - That zone of the shore or beach lying between the foreshore and the coastline and acted upon by waves only during severe storms especially when combined with exceptionally high water. Also backbeach. It comprises the BERM or BERMS.

BAR - A submerged or emerged embankment of sand, gravel, or other unconsolidated material built on the sea floor in shallow water by waves and currents.

BATHYMETRY - The measurement of depths of water in oceans, seas, and lakes; also information derived from such measurements.

BEACH - The zone of unconsolidated material that extends landward from the low water line to the place where there is marked change in material or physiographic form, or to the line of permanent vegetation (usually the effective limit of storm waves). The seaward limit of a beach - unless otherwise specified - is the mean low water line. A beach includes FORESHORE and BACKSHORE.

BEACH BERM - A nearly horizontal part of the beach or backshore formed by the deposit of material by wave action. Some beaches have no berms, others have one or several.

BEACH EROSION - The carrying away of beach materials by wave action, tidal currents, littoral currents, or wind.

BLUFF - A high steep bank or cliff.

¹A more detailed listing of terminology used in coastal engineering is given in *A Glossary of Coastal Engineering Terms*, MP 2-72, and the *Shore Protection Manual*, Vol. III.

BREAKER - A wave breaking on a shore, over a reef, etc. Breakers may be classified into four types:

Spilling - bubbles and turbulent water spill down front face of wave. The upper 25 percent of the front face may become vertical before breaking. Breaking generally across over quite a distance.

Plunging - crest curls over air pocket; breaking is usually with a crash. Smooth splash-up usually follows.

Collapsing - breaking occurs over lower half of wave. Minimal air pocket and usually no splash-up. Bubbles and foam present.

Surging - wave peaks up, but bottom rushes forward from under wave, and wave slides up beach face with little or no bubble production. Water surface remains almost plane except where ripples may be produced on the beachface during runback.

BREAKWATER - A structure protecting a shore area, harbor, anchorage, or basin from waves.

BULKHEAD - A structure or partition to retain or prevent sliding of the land. A secondary purpose is to protect the upland against damage from wave action.

CLIFF - A high, steep face of rock; a precipice.

COAST - A strip of land of indefinite width (may be several miles) that extends from the shoreline inland to the first major change in terrain features.

COASTLINE - (1) Technically, the line that forms the boundary between the COAST and the SHORE. (2) Commonly, the line that forms the boundary between the land and the water.

CONTOUR - A line on a map or chart representing points of equal elevation with relation to a DATUM. It is called an Isobath when connecting points of equal depth below a datum.

COVE - A small, sheltered recess in a coast, often inside a larger embayment.

CURRENT, LITTORAL - Any current in the littoral zone caused primarily by wave action, e.g., longshore current, rip current.

CURRENT, LONGSHORE - The littoral current in the breaker zone moving essentially parallel to the shore, usually generated by waves breaking at an angle to the shoreline.

DATUM, PLANE - The horizontal plane to which soundings, ground elevations, or water surface elevations are referred. Also Reference Plane. The plane is called a Tidal Datum when defined by a certain phase of the tide. The following datums are ordinarily used on hydrographic charts:

Mean Low Water - Atlantic coast (U.S.), Argentina, Sweden, and Norway;

Mean Lower Low Water - Pacific coast (U.S.);

Mean Low Water Springs - United Kingdom, Germany, Italy, Brazil, and Chile;

LOW WATER DATUM - Great Lakes (U.S. and Canada);

Lowest Low Water Springs - Portugal;

Low Water Indian Springs - India and Japan;

Lowest Low Water - France, Spain, and Greece.

A common datum used on topographic maps is based on Mean Sea Level.

DEEP WATER - Water so deep that surface waves are little affected by the ocean bottom. Generally, water deeper than one-half the surface wavelength is considered deep water.

DIKE (DYKE) - A wall or mound built around a low-lying area to prevent flooding.

DOWNDRIFT - The direction of predominant movement of littoral materials.

DRIFT (noun) - (1) Sometimes used as a short form for Littoral Drift.

(2) The speed at which a current runs. (3) Also floating material deposited on a beach (driftwood). (4) A deposit of a continental ice sheet, as a drumlin.

DUNES - (1) Ridges or mounds of loose, wind-blown material, usually sand. (2) Bed Forms smaller than bars but larger than ripples that are out of phase with any water-surface gravity waves associated with them.

EROSION - The wearing away of land by the action of natural forces. On a beach, the carrying away of beach material by wave action, tidal currents, littoral currents, or by deflation.

FETCH - The area in which SEAS are generated by a wind having a rather constant direction and speed. Sometimes used synonymously with Fetch Length. Also Generating Area.

FOREDUNE - The front dune immediately behind the backshore.

FORESHORE - The part of the shore lying between the crest of the seaward berm (or upper limit of wave wash at high tide) and the ordinary low water mark, that is ordinarily traversed by the uprush and backrush of the waves as the tides rise and fall.

GROIN (British, GROYNE) - A shore protection structure built (usually perpendicular to the shoreline) to trap littoral drift or retard erosion of the shore.

GROIN SYSTEM - A series of groins acting together to protect a section of beach. Commonly called a groin field.

GULF - A large embayment in a coast; the entrance is generally wider than the length.

HEADLAND (HEAD) - A high steep-faced promontory extending into the sea.

HIGH WATER LINE - In strictness, the intersection of the plane of mean high water with the shore. The shoreline delineated on the nautical charts of the U.S. Coast and Geodetic Survey is an approximation of the high water line. For specific occurrences, the highest elevation on the shore reached during a storm or rising tide, including meteorological effects.

IMPERMEABLE GROIN - A groin through which sand cannot pass.

INLET - (1) A short, narrow waterway connecting a bay, lagoon, or similar body of water with a large parent body of water. (2) An arm of the sea (or other body of water), that is long compared to its width, and may extend a considerable distance inland.

ISTHMUS - A narrow strip of land, bordered on both sides by water, that connects two larger bodies of land.

JETTY - (1) (U.S. usage) On open seacoasts, a structure extending into a body of water, and designed to prevent shoaling of a channel by littoral materials, and to direct and confine the stream or tidal flow. Jetties are built at the mouth of a river or tidal inlet to help deepen and stabilize a channel. (2) (British usage) Jetty is synonymous with "wharf" or "pier."

LAGOON - A shallow body of water, as a pond or lake, usually connected to the sea.

LEADLINE - A line, wire, or cord used in sounding. It is weighted at one end with a plummet (sounding lead).

LEVEE - A dike or embankment to protect land from inundation.

LITTORAL - Of or pertaining to a shore, especially of the sea.

LITTORAL DRIFT - The sedimentary material moved in the littoral zone under the influence of waves and currents.

LITTORAL TRANSPORT - The movement of littoral drift in the littoral zone by waves and currents. Includes movement parallel (longshore transport) and perpendicular (on-offshore transport) to the shore.

LITTORAL TRANSPORT RATE - Rate of transport of sedimentary material parallel to or perpendicular to the shore in the littoral zone. Usually expressed in cubic yards (meters) per year. Commonly used as synonymous with LONGSHORE TRANSPORT RATE.

LITTORAL ZONE - In beach terminology, an indefinite zone extending seaward from the shoreline to just beyond the breaker zone.

LONGSHORE - Parallel to and near the shoreline.

LONGSHORE TRANSPORT RATE - Rate of transport of sedimentary material parallel to the shore. Usually expressed in cubic yards (meters) per year. Commonly used as synonymous with LITTORAL TRANSPORT RATE.

LOW WATER DATUM - An approximation to the plane of mean low water that has been adopted as a standard reference plane.

MARSH - An area of soft, wet, or periodically inundated land, generally treeless and usually characterized by grasses and other low growth.

MOLE - In coastal terminology, a massive land-connected, solid-fill structure of earth (generally revetted), masonry, or large stone. It may serve as a breakwater or pier.

NEARSHORE (ZONE) - In beach terminology an indefinite zone extending seaward from the shoreline well beyond the breaker zone. It defines the area of NEARSHORE CURRENTS.

NEARSHORE CURRENT SYSTEM - The current system caused primarily by wave action in and near the breaker zone, and which consists of four parts: The shoreward mass transport of water; longshore currents; seaward return flow, including rip currents; and the longshore movement of the expanding heads of rip currents.

NOURISHMENT - The process of replenishing a beach. It may be brought about naturally, by longshore transport, or artificially by the deposition of dredged material.

OFFSHORE - (1) In beach terminology, the comparatively flat zone of variable width, extending from the breaker zone to the seaward edge of the Continental Shelf. (2) A direction seaward from the shore.

OUTFALL - A structure extending into a body of water for the purpose of discharging sewage, storm runoff, or cooling water.

OVERTOPPING - Passing of water over the top of a structure as a result of wave runup or surge action.

OVERWASH - That portion of the uprush that carries over the crest of a berm or of a structure.

PENINSULA - An elongated body of land nearly surrounded by water, and connected to a larger body of land.

PERMEABLE GROIN - A groin with openings large enough to permit passage of appreciable quantities of littoral drift.

PIER - A structure, usually of open construction, extending out into the water from the shore, to serve as a landing place, a recreational facility, etc., rather than to afford coastal protection. In the Great Lakes, a term sometimes improperly applied to jetties.

PILE - A long, heavy timber or section of concrete or metal to be driven or jetted into the earth or seabed to serve as a support or protection.

PILE, SHEET - A pile with a generally slender flat cross section to be driven into the ground or seabed and meshed or interlocked with like members to form a diaphragm, wall, or bulkhead.

POCKET BEACH - A beach, usually small, in a coastal reentrant or between two littoral barriers.

POINT - The extreme end of a cape, or the outer end of any land area protruding into the water, usually less prominent than a cape.

PORT - A place where vessels may discharge or receive cargo; may be the entire harbor including its approaches and anchorages, or may be the commercial part of a harbor where the quays, wharves, facilities for transfer of cargo, docks, and repair shops are situated.

PROFILE, BEACH - The intersection of the ground surface with a vertical plane; may extend from the top of the dune line to the seaward limit of sand movement.

PROMONTORY - A high point of land projecting into a body of water; a HEADLAND.

QUAY (Pronounced KEY) - A stretch of paved bank, or a solid artificial landing place parallel to the navigable waterway, for use in loading and unloading vessels.

RECEDITION (of a beach) - (1) A continuing landward movement of the shoreline. (2) A net landward movement of the shoreline over a specified time.

REVETMENT - A facing of stone, concrete, etc., built to protect a scarp, embankment, or shore structure against erosion by wave action or currents.

RIDGE, BEACH - A nearly continuous mound of beach material that has been shaped up by wave or other action. Ridges may occur singly or as a series of approximately parallel deposits.

RIPARIAN RIGHTS - The rights of a person owning land containing or bordering on a water course or other body of water in or to its banks, bed, or waters.

RUBBLE-MOUND STRUCTURE - A mound of random-shaped and random-placed stones protected with a cover layer of selected stones or specially shaped concrete armor units. (Armor units in primary cover layer may be placed in orderly manner or dumped at random.)

RUNUP - The rush of water up a structure or beach on the breaking of a wave. Also UPRUSH. The amount of runup is the vertical height above stillwater level that the rush of water reaches.

SCARP, BEACH - An almost vertical slope along the beach caused by erosion by wave action. It may vary in height from a few inches to several feet, depending on wave action and the nature and composition of the beach.

SCOUR - Removal of underwater material by waves and currents, especially at the base or toe of a shore structure.

SEAWALL - A structure separating land and water areas, primarily designed to prevent erosion and other damage due to wave action. See also BULKHEAD.

SEICHE - (1) A standing wave oscillation of an enclosed water body that continues, pendulum fashion, after the cessation of the originating force, which may have been either seismic or atmospheric. (2) An oscillation of a fluid body in response to a disturbing force having the same frequency as the natural frequency of the fluid system. Tides are now considered to be seiches induced primarily by the periodic forces caused by the sun and moon. (3) In the Great Lakes area, any sudden rise in the water of a harbor or a lake whether or not it is oscillatory. Although inaccurate in a strict sense, this usage is well established in the Great Lakes area.

SETUP, WAVE - Superelevation of the water surface over normal surge elevation due to onshore mass transport of the water by wave action alone.

SHALLOW WATER - (1) Commonly, water of such a depth that surface waves are noticeably affected by bottom topography. It is customary to consider water of depths less than one-half the surface wavelength as shallow water. See DEEP WATER. (2) More strictly, in hydrodynamics with regard to progressive gravity waves, water in which the depth is less than 1/25 the wavelength.

SHORE - The narrow strip of land in immediate contact with the sea, including the zone between high and low water lines. A shore of unconsolidated material is usually called a beach.

SHORELINE - The intersection of a specified plane of water with the shore or beach. (e.g., the highwater shoreline would be the intersection of the plane of mean high water with the shore or beach.) The line delineating the shoreline on U.S. Coast and Geodetic Survey nautical charts and surveys approximates the mean high water line.

SLIP - A berthing space between two piers.

SOUNDING - A measured depth of water. On hydrographic charts the soundings are adjusted to a specific plane of reference (Sounding Datum).

SOUNDING LINE - A line, wire, or cord used in sounding. It is weighted at one end with a plummet (sounding lead). Also LEADLINE.

SPIT - Small point of land or a narrow shoal projecting into a body of water from the shore.

STILLWATER LEVEL - The elevation that the surface of the water would assume if all wave action were absent.

SURF - The wave activity in the area between the shoreline and the outermost limit of breakers.

SURF ZONE - The area between the outermost breaker and the limit of wave uprush.

TOMBOLO - A bar or spit that connects or "ties" an island to the mainland or to another island.

UPDRIFT - The direction opposite that of the predominant movement of littoral materials.

UPRUSH - The rush of water up onto the beach following the breaking of a wave. Also Swash, RUNUP.

WATERLINE - A juncture of land and sea. This line migrates, changing with the tide or other fluctuation in the water level. Where waves are present on the beach, this line is also known as the limit of backrush. (Approximately the intersection of the land with the stillwater level.)

WAVE DIRECTION - The direction from which a wave approaches.

WAVE HEIGHT - The vertical distance between a crest and the preceding trough.

WAVELLENGTH - The horizontal distance between similar points on two successive waves measured perpendicular to the crest.

WIND SETUP - (1) The vertical rise in the stillwater level on the leeward side of a body of water caused by wind stresses on the surface of the water. (2) The difference in stillwater levels on the windward and the leeward sides of a body of water caused by wind stresses on the surface of the water. (3) Synonymous with Wind Tide and Storm Surge. Storm Surge is usually reserved for use on the ocean and large bodies of water. WIND SETUP is usually reserved for use on reservoirs and smaller bodies of water.

APPENDIX B

ALTERNATIVE SHORE PROTECTION METHODS DATA SHEET

1. CODE NUMBER: 73 ASPM: 00002
DATE: 13 December 1974
BY: A.J. Combe
2. PHOTOGRAPH:



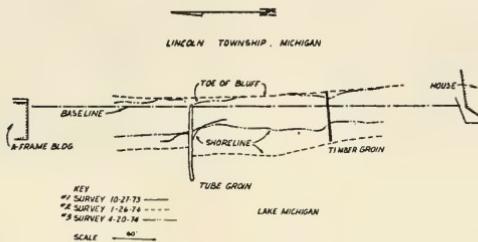
3. TYPE: *Longard Tube Groin*
4. OWNER: *State of Michigan, Department of Natural Resources*
5. LOCATION: *Lincoln Township near Stevensville (T-55 - R. 19W)
in Berrien County, Michigan*
6. DATE CONSTRUCTED: *October 1973*

7. PHYSICAL ENVIRONMENT:

- a. General: Moderate Energy Area
- b. Wave climate: Height: 1.7 feet¹; Period: 4.2 seconds¹
- c. Tides - water levels: No tides, lake level dependent on runoff
- d. Currents: 0.29 foot per second to south.¹
- e. Winds: Southerly and offshore winds predominate.¹
- f. Sediments: Fine sand

8. DESIGN DATA:

- a. Sketch:



STRUCTURAL DIMENSIONS: DIAMETER: 40 INCHES; LENGTH: 100 FEET

- b. Forces: Not known

c. Structural Behavior: Tube settled as a result of beach erosion during storms. Tube subject to puncture, repair possible. Structure reported to have trapped sand and protected the bluff.

9. ENVIRONMENTAL IMPACT:

- a. Physical: Slight effects
- b. Biota: Slight and temporary effects
- c. Aesthetics: Strong contrast between black tube and white beach.

¹Annual average from observed surf data.

10. CONTRACTOR: Information unavailable.
11. COST OF BASIC STRUCTURE: \$57.00 per foot of structure (installed).
12. REFERENCE:
 - a. BRATER, E.F., ARMSTRONG, J.A., and MCGILL, M.R., "Shore Erosion Engineering Demonstration Project Post-Construction-Season Progress--Interim Report," Coastal Zone Laboratory, University of Michigan, Feb. 1974.
 - b. JAKOBSEN, P.R., and NIELSON, A.H., "Some Experiments with Sand Filled Flexible Tube," Proceedings of 12th Coastal Engineering Conference, Washington, D.C., 1970.

13. NOTES:

Reference a: The tube has shown good resistance to the forces acting on it; it is essential to pay careful attention to the problem of bottom protection...some attempts were tried with filter cloth but were not properly executed.

Reference b: The tube settled to conform with the winter profile; but indicates that the structure trapped a slight amount of sand.

U.S. Coastal Engineering Research Center.
Guidelines for monitoring shore protection structures in the Great Lakes. Ft. Belvoir, Va., U.S. Coastal Engineering Research Center, 1974.
38p. illus. (U.S. Coastal Engineering Research Center, Miscellaneous paper 2-75).
Bibliography: p. 25.

Extent of wave damage to shores is difficult to predict; shore behavior should be observed for need of a shore protection structure. Optimum and minimum plans for recording shoreline changes and monitoring groins, seawalls, revetments, and offshore breakwaters are given. Simple shore erosion computations and a data analysis program are presented.

1. Great Lakes. 2. Beach erosion. 3. Shore protection. 4. Groins. 5. Breakwaters. 6. Revetments. I. Title (Series)

TC203 .U581mp no.2-75 623 .U581mp

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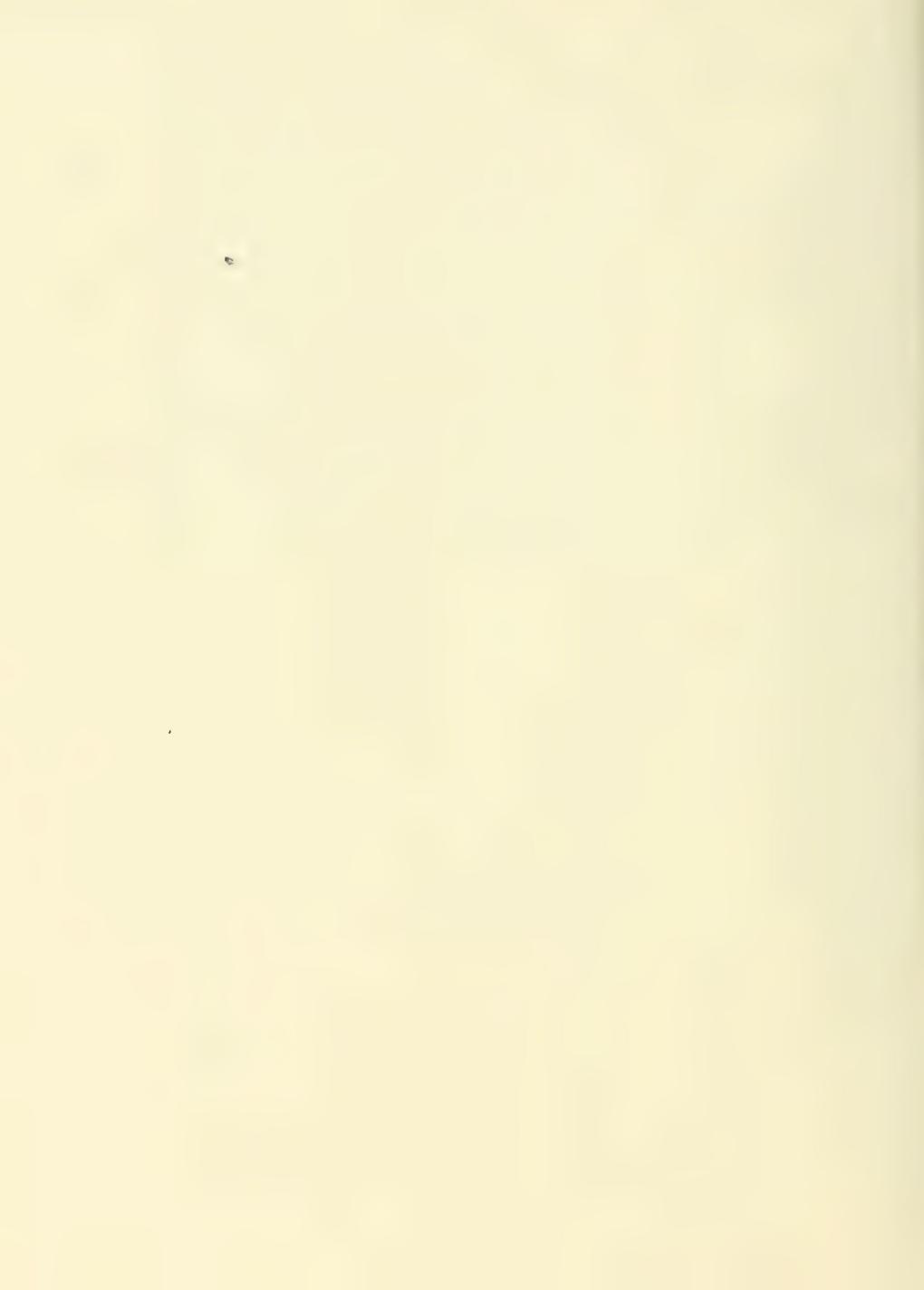
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